oppositely charged (*i.e.* the walls encroaching on the cavity), the far side similarly charged (the cavity encroaching on the walls), and the pressure on the fluid in the cavity being increased or diminished in correspondence with the change of pressure in the charged or inducing cavity. In other words, conductors rise in potential when brought near a positively charged body.

The actual changes in volume necessary to the strain of these cavities are a defect in the analogy. To avoid this objection, one will have to accept a dual view of electricity—a sort of two-fluid theory, which many phenomena urge one to accept, but about which I will say nothing to-night. It is sufficient at first to grasp the one-fluid ideas.

Return Circuit.—Sometimes a difficulty is felt about electricity flowing in a closed circuit—as, for instance, in signalling to America and using the earth as a return circuit: the question arises, How does the electricity find its way back?

The difficulty is no more real than if a tube were laid to America with its two ends connected to the sea and already quite full. If now a little more sea-water were pumped in at one end, an equal quantity would leave the other end, and the disturbed level of the ocean would readjust itself. Not the same identical water would return, but an equal quantity would return. That is all one says in electricity. One cannot label and identify electricity.

To imitate the inductive retardation of cables, the tube should have slightly elastic walls; to imitate the speed of signalling, the water must be supposed quite incompressible, not elastic as it really is, or each pulse would take three-quarters of an hour to go.

Condensers.—Returning to the subject of charging bodies electrically, how is one to consider the fact that bringing an earth-plate near a conductor increases its capacity so greatly, enabling the same pressure to force in a much larger quantity of fluid? how is one to think of a condenser, or Leyden jar?

In the easiest possible way, by observing that the bringing near an earth-connected conductor is really *thinning down the dielectric* on all sides of the body.

The thin-walled elastic medium of course takes less force to distend it a given amount than a thick mass of the same stuff took. A Leyden jar is like a cavity with quite thin walls—in other words, it is like an elastic bag.

But if you thin it too far, or strain it too much, the elastic membrane may burst: exactly, and this is the disruptive discharge of a jar, and is accompanied by a spark. Sometimes it is the solid dielectric which breaks down permanently. Ordinarily it is merely the air; and, since a fluid insulator constitutes a self-mending partition, it is instantaneously as good as new again.

There are many things of interest and importance to study about a Leyden jar. There is the fact that if insulated, it will not charge: the potential of both inner and outer coatings rises equally; that, in order to charge it, for every positive spark you give to the interior an equal positive spark must be taken from the exterior. There is the charging and the discharging of it by alternate contacts, as by an oscillating ball; and there are the phenomena of the spark-discharge itself.

But, as you know, *all* charging is really a case of a Leyden jar. The outer coat must always be somewhere—the walls of the room, or the earth, or something—you always have a layer of dielectric between two charges—the so-called induced and the inducing charge. You cannot charge one body alone.

To illustrate the phenomena of charge, I will now call your attention to these diagrams—which less completely but more simply than hydraulic illustrations, serve to make the nature of the phenomena manifest.

(*To be continued.*)

ON THE TEACHING OF CHEMISTRY.[1]

THE question is being often asked, Why does chemistry progress so slowly in this country? Different answers, all more or less true, may be given; one answer that has not, I think, been sufficiently insisted on is: Because chemistry is so little taught.

Classes, nominally in chemistry, are conducted in many schools, and in almost all the colleges, of the country; but I assert that very little of what is taught is really chemistry. For what is it that is taught? On the one hand, catalogues of so-called facts detached from reasoning and from generalizations; on the other hand, definitions and generalizations and speculations detached from the facts on which they rest. But neither detached facts, however accurately stated, nor definitions, in however sharply-cut words they are contained, nor speculations, however interesting they may be, are science; and chemistry really is a branch of natural science.

It is admitted by all that hydrogen is a colourless, odourless gas, 14·435 times lighter than air, produced by the interaction of dilute sulphuric acid and zinc, combustible, condensable to a liquid at very low temperatures. These statements are facts; but when the student of chemistry is required to read, and if possible to remember, such facts as these about each of the elements and its compounds, the statements cease to be facts to him, and become false, inasmuch as they cover up and hide the really important facts regarding the interactions of elements and compounds, and regarding the connexions between changes of composition and changes of properties, which form the subject-matter of chemistry.

I have known students have at their finger-ends the properties of all the elements—as these properties are detailed in the ordinary text-books—and yet be almost wholly ignorant of chemistry.

And I have also known students ready at a moment's notice to repeat the orthodox definitions of atomic and molecular weights, or to draw structural formulæ of complex minerals, or to speak fluently about double bonds and unsaturated units of affinity, and yet be quite innocent of any knowledge of chemistry.

A fatal distinction is too often drawn by chemical teachers between the facts on which chemical science rests, and reasoning and generalizing on these facts: the former, that is statements of detached facts, is called chemistry; the latter, that is reasoning on facts and generalizing to principles, is called chemical philosophy. I believe strongly that there are not two chemistries, but one chemistry. If chemical teachers were quite decided as to what they ought to teach, we might hope for marked advances in our science.

My own experience in teaching chemistry convinces me that it is a very difficult subject both to teach and to learn. Of course there is no great difficulty in restating to a class what is printed in the text-book, and occasionally enlivening the routine by a few experiments; nor does it require high mental capacities and training to tell the laboratory student that bottle A contains a double salt, to be analyzed by the help of the tables on page so-and-so of the book. But do not let us call this kind of thing teaching chemistry. To teach chemistry well requires experience and an educated mind. It is not easy to hit the golden mean. If the teacher despises facts his reasoning becomes absurd, because it is based on nothing; his principles become only speculations; and his laws merely phrases. If he disregards principles, generalizations, and theories, his facts become false, and when facts are false (as they often are) they are deadly, and kill those that trust in them.

Chemistry is a branch of natural science; it deals with one class of natural occurrences, it observes and experiments on these occurrences, it classifies and generalizes, and tries to ascend from empirical generalizations to natural laws. The business of the teacher of chemistry I take to be to make his pupil understand the methods of chemistry; to select typical facts and put these before the learner so that he may to some extent see their relative importance in the general scheme of well-built knowledge; to show the student how complex are the phenomena chemistry investigates, and how she simplifies that she may explain; to imbue him with some of that fine enthusiasm without which no great work is possible, by presenting to him glimpses of the greatness of the subject he is studying, and the importance of the prosecution of the study; and thus to build up in the student a scientific spirit, until at last the teacher and the learner are merged in their common investigation of nature.

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[1] A Paper read before Section B of the British Association at Manchester, by M. M. Pattison Muir, M.A., Fellow of Gonville and Caius College, Cambridge.

In teaching chemistry the all-important things appear to me to be chiefly four: (1) to teach so that the student shall acquire real knowledge; (2) to carefully select both the facts and the reasoning to be set before the student; (3) to impress the learner with the importance and value of what he is learning as a part of that orderly and methodized study of nature which we call science; (4) to teach without fear of the examiner.

Real knowledge of chemistry can only be acquired by connecting the experimental work in the laboratory with chemical reasoning and with the principles of the science. This is rarely done in our chemical schools. The student generally hears lectures on chemistry, or at least on the materials from which chemical science is constructed; he sees experiments performed that have some connexion with what the lecturer teaches; then he goes into the laboratory and day after day performs qualitative analyses, for the most part by rule of thumb. The learner, especially the beginner, cannot connect what he is taught in lectures, and told to read in books, with what he does in the laboratory. The introduction of a well-arranged and properly graduated system of practical chemistry, is, in my opinion, one of the things which will do much to hasten the advance of chemistry among us. The work done in the laboratory must be directly connected with the lecture-work and the reading of the student; it must be progressive, beginning with easy experiments and leading the student onwards until he is able to investigate chemical occurrences for himself; and it must be arranged so that as the experimental work becomes more difficult the reasoning on the results becomes more close and accurate.

Such a course of practical chemistry can be arranged without any complicated laboratory appliances. (I may say parenthetically that in my opinion the building of luxuriously fitted laboratories has not been an unmixed gain to chemical science.)

In the course of laboratory work which seems to me to be called for, the student would begin with easy experiments on chemical and physical change, on the distinction between elements and not-elements (this would involve quantitative measurements), and on the classification of not-elements into mixtures and compounds. He would then proceed to classify compounds into acids, bases, and salts, working through well-chosen examples of each class. He would learn by his own experiments what is meant by "the replaceable hydrogen of acids," and by the classification of acids in accordance with their "basicity." He would study classes of elements, and so get a real grasp of the reasons for placing certain elements in one class, and of the principles of chemical classification. After hearing in the lecture-room about the properties of the members of a class of elements—say the iron class—he would at once go into the laboratory and himself prepare typical similar compounds of these elements. He would then turn to the conditions of chemical action; he would practically learn what an ordinary chemical equation teaches, and he would be impressed, by the results of his own experiments, with the importance of determining the conditions under which chemical changes occur, and with the many and varied facts regarding even every-day chemical changes which are not expressed in our chemical notation. The study of the conditions of chemical change would lead on to the study of affinity, of dissociation, and of allied subjects.

Turning again to the study of composition, the student would make determinations of the equivalent weights of a series of similar compounds, and also of several elements; he would determine the molecular weights of a few gaseous bodies, and the atomic weights of one or two elements. He would then proceed to study experimentally some of the methods whereby light is thrown on the constitutions of compounds. For instance, he would determine the specific volumes of a series of carbon compounds, the rates of etherification of a series of alcohols, and the nature of the products of the reaction of such a compound as phosphorus pentachloride with carbon compounds belonging to different classes but showing similarities of composition. Thus the molecular and atomic theory would become a reality to him. Finally, he would be required to repeat an investigation before undertaking himself to advance into the realm of the unknown.

In such a course as this the student would study a series of carefully selected facts; his reading and laboratory work would go hand in hand, each would react upon the other, and so he would be saved from the danger of attempting to draw a distinction between two things which are truly one—chemistry and chemical philosophy.

In selecting the facts and reasoning to be placed before the student of chemistry I think we should now finally abandon the method of treating the elements individually, and rather consider them in groups or classes. If this is done the student soon acquires a fair knowledge of chemical facts; he learns the compositions and properties of groups of similar compounds, he traces some of the connexions between changes of composition and of properties in analogous compounds. By considering the elements in groups the artificial difference between rare and common elements disappears, and this, I think, is a decided gain. The learner also begins to recognize that there are reasons for classing certain elements and compounds together; he sees that order and law pervade the vast domain of chemistry; he connects the constant *atomic weight* with the position of each element in the scheme of classification; and so he gains a basis on which he may rest the superstructure of facts as they are presented to him. This method of treatment inspires the learner with the hope that it is possible to get a firm hold of the subject he is studying. The method is progressive: principles are seen to arise out of the classes of facts considered; each event examined appears as at once the cause and the consequence of other events; generalizing on facts accompanies the acquisition of the facts themselves.

But if the student is expected to learn the properties of each element and its compounds, proceeding from element to element, he generally completely fails to grasp the connexion between similar elements; indeed, he usually and not unnaturally inquires why he should be burdened by these details, which seem to him only unmeaning facts: if he knows and can repeat the properties of half-a-dozen elements, what the better is he for knowing and being able to repeat the properties of a dozen more? The additional facts do not seem to help him to a knowledge of chemistry. And so he either despairs of finding any guiding light in the maze of facts, or he falls into the error of supposing that the maze in which he is wandering without a clue is chemistry. It is the old school method again, which teaches the uselessness of knowledge. When we look back on our school days do we not regret the hours wasted on learning rules and exceptions to rules? Do we not remember how hopeless it all was? how little we advanced? how we spent a year on this subject and a year on that, and failed to gain a grip of any? Did we not sometimes believe that every branch of knowledge was merely a collection of rules? Do not then let us teach science as we learned grammar; else the burden we attempt to bind on the shoulders of our pupils will be more grievous even than that which we bore ourselves in our youth.

The third point on which I would insist is that chemistry should be taught so as to impress the student with the importance of the subject, and with the fact that chemistry is a living and growing part of the scientific study of nature. A teacher of any branch of natural science must thoroughly believe in his subject; and he must have a vivid and active imagination. The subject he has to teach is so immense that, unless his imagination is clear and active, he forms blurred and inaccurate images of the natural occurrences which he wishes to put before his pupils, and so presents them with poor distorted pictures in place of the vivid and vivifying realities of nature.

I see no way of impressing chemical students with the greatness of the subject of their study other than that of constantly keeping before them the many-sidedness of the problems they are trying to solve; of constantly showing how even the smallest, and apparently quite detached, fact is really in living connexion with the whole science; and from time to time of reminding them that the subject of their study is but one part of natural science and is closely connected with many other branches of scientific investigation. But these things can be done only by the teachers and the taught constantly working side by side in the laboratory at some of those apparently simple chemical problems which branch off in many directions, and thus together gaining a real grasp of the many-sidedness of the subject they are studying. The student is thus convinced that, although "there are no boundaries in nature," yet it is necessary for us to draw boundary lines; he also learns the importance of those very facts which, when separated from each other and from the principles that bind them together, retain only a negative value. Science is more than knowledge, and we must make our students realize this. To be in touch with nature is what we aim at; and knowledge alone will not gain this end. We are striving for a real, living, imaginative, acquaintance with the laws of the universe, in order that our lives may thus become "rich and full and satisfying through realities and not through dreams."

Finally, I think that fear of the examiner acts very prejudicially on much of the chemical teaching of this country, more especially on the teaching in schools. For after all—I speak as an examiner—even the youngest examiner is fallible. He is not so very terrible a person as some teachers seem to suppose. Not unfrequently he is a foolish person who knows but little chemistry, and has recourse to text-books for good tips.

If it is really chemistry that is taught, a good examiner will soon find out that the students have learnt the real thing, and a bad examiner will perhaps be incited to leave his rules and definitions, and attempt to gain some real knowledge of the subject in which he examines.

I think that much more care ought to be exercised in selecting those who are to examine the results of the chemical teaching given in schools. Even the seats of the higher learning are scarcely yet impressed with the really tremendous importance of sound scientific teaching; and they still too often wish to get examiners who will set papers for schools in half-a-dozen subjects, instead of selecting men who have made special study of special branches of science, and asking them to examine in their own subjects.

I have not directly insisted much on the importance of research. Of course the aim of all scientific teaching must be to train up men competent to investigate nature for themselves. But unless the men are properly trained, and are taught by the examples as well as by the precepts of their teachers what true scientific research is, they will only add a few more facts to that vast gathering of these "brute beasts of the intellectual domain" which is so often but so falsely called chemistry; and they will persuade themselves that in doing this they are advancing the scientific study of nature.

I would sum up what I have tried to say in a few words. The teaching of chemistry is still too much under the trammels of the old scholastic methods; it stands too much in fear of books, and rules, and definitions. The teacher who is in earnest about his work must break through rules, he must "swallow all formulæ," he must go constantly to nature and take his pupils with him; and his reward will be great.

BOTANY OF THE RIUKIU (LOOCHOO) ISLANDS.

WITHIN the last score of years much light has been thrown upon our knowledge of the flora of Japan. We still, however, know little about the flora of the groups of islands which lie scattered off the coast of her southern boundary. It is true that some botanical collections made during the last few years have shown a certain insight into the flora of some of the archipelago known as the Riukiu or Loochoo Islands, but it is equally true that most of the islands remain as yet absolutely uninvestigated. Since careful studies of the materials, both literature and specimens, scanty as they are, have shown that the flora of the Riukiu Islands form obviously the connecting link between that of Japan, on the one hand, and, on the other, those of South-Eastern China and the Indo-Malayan region through the islands of Hong Kong and Formosa, it seems necessary to take a clear view of the flora of the Riukiu Islands where the boundary lines of those of the two above main regions overlap. Hence it may be worth while to offer a brief summary of our present knowledge of the flora of the Riukiu Islands, taken not only from the materials already presented to the scientific world, but also from those works which have been brought out by the hands of native botanists of Eastern Asia, which have not yet been accessible to most of the Western men of science.

We observe that the earliest records of the plants of the Riukiu Islands are found in that section of the work entitled "Chuzan Denshinroku," or "Records of the Riukiu Islands," which deals with the natural products of that archipelago. These records are detailed in an extended form in another work, the "Riukiu Sambutsushi," or, "The Natural Products of Riukiu." But, as to the works which treat exclusively of the botany of the Riukiu Islands, reference should be made to the "Riukiu Sōmoku Shin Dsu" ("Illustrations of the Plants of Riukiu") and to "Shitsumon Honzō" ("Queries on the Botany of the Riukiu Islands"). The latter, on account of the excellence of its illustrations of plants, and also on account of some interesting facts connected with the preparation of the work, demands here special mention. The author, Go Keishi, a physician of the Island of Okinawa, collected during many years not only the plants of the island in which he lived, but also specimens from the Isles of Takara and Yokō, both of which are situated near 29° N. lat. and 129° E. long. He drew figures, and gave brief descriptions, of these plants, accompanied by dried specimens, forming a collection of about seventy or eighty species of plants at each time, and sent them annually, between 1781–85, to China, in order to acquire further information about those plants which he considered to be doubtful. No fewer than forty-five Chinese representative physicians and herbalists of that time, in various parts of the country,